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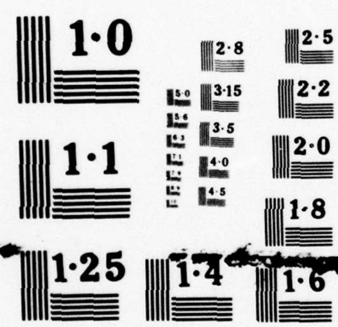

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NRL Memorandum Report 3764

The 1977 NRL Air Quality Data

A. STAMULIS

Radiological and Environmental Protection Staff

April 1978

NAVAL RESEARCH LABORATORY
Washington, D.C.

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The air quality data included in this report are for the calendar year 1977. The present report is the third annual summary of air quality data obtained by the NRL air monitoring program initiated in 1975. The variables reported include ozone (O_3), sulfur dioxide (SO_2), nitrogen dioxide (NO_2), non-methane hydrocarbons (RHC), carbon monoxide (CO), wind speed, and wind direction. The data are obtained from monthly computer printouts of the air quality for different time-averages of interest. A yearly review of the main features of the air quality data is presented in this report.

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ABSTRACT

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CONTENTS

THE 1977 NRL AIR QUALITY DATA

INTRODUCTION

This report is the third in a continuing series of annual summaries of the air quality data measured at the NRL air monitoring station (1,2). The present review includes data for the calendar year 1977. The variables measured were ozone (O_3), sulfur dioxide (SO_2), nitrogen dioxide (NO_2), total hydrocarbons (THC), methane (CH_4), carbon monoxide (CO), wind speed, and wind direction. For ease of presentation, only the difference between THC and CH_4 will be reported, i.e., the non-methane hydrocarbons (RHC), for a given time-averaging period.

In this report only the main features of the air quality data will be presented. In a future report a more comprehensive and detailed analysis will be given, and will include several years data.

BACKGROUND

The current air monitoring program became operational during January 1975 for the continuous measurement of pollutants, gases, and meteorological conditions of interest. At the present time, the NRL air monitoring station is located in Building 207, Room 409. A schematic diagram of the NRL air monitoring station is shown in Fig. 1. Details of the air monitoring station, the instruments in use, and the computer program for analyzing the air quality data have been discussed in previous publications (1,2,3,4).

GENERAL INFORMATION

The physical location of the Laboratory, and the air monitoring station lies in the southwest quadrant of the District of Columbia (Washington, D. C.). In close proximity to the Laboratory are also portions of Maryland (Prince George's County) and Virginia (city of Alexandria, Arlington County). Specifically, the Laboratory is bounded on the north by Bolling Air Force Base, east by Route 295, south by the D.C. Sewage Treatment Plant, and west by the

Note: Manuscript submitted March 20, 1978.

Potomac River. Inspection of Fig. 2, a radial and directional map of NRL and vicinity, clarifies the geography.

The immediate area surrounding the Laboratory may be considered as part of the urban complex including commercial, light industry, and residential facilities. It is assumed that the air quality data obtained within this area is biased with respect to man-made emissions and mostly from combustion sources (stationary-mobile, area-line-point, ground level-elevated, and continuous-intermittent). It is not clear how or how much non-combustion and natural emission sources contribute to the pollutant measurements currently being made at the NRL air monitoring station. However, it should be kept clear that the concentration measurement of a pollutant, within a given time-averaging period (5-minutes, 1-hour, 24-hour, etc.), is the total concentration present in the atmosphere from combustion, non-combustion, and background sources. Furthermore, at the time of measurement some part of the pollutant concentrations are "fresh" (local) and part are "aged" (long distance transport).

Emission sources include fuel combustion, industrial processes, transportation, solid waste disposal, solvent evaporation losses, biological oxidation, microbial action, and vegetation. Some of these sources may preferentially emit one predominant pollutant in greater amounts than the other pollutants. For example, most fuel combustion sources emit all the classes of pollutants (carbon, nitrogen, and sulfur oxide gases, hydrocabons, and particulates), but whereas coal burning emits copious quantities of sulfur gases, fuel oil burning does not. In another example, motor vehicle exhaust emissions are the predominant source of carbon monoxide, while for other combustion sources carbon monoxide emissions are less predominant.

AIR QUALITY DATA AND RESULTS

Valid Hourly Observations

Table 1 lists the valid hourly observations for each variable measured at the NRL air monitoring station during each month of the calendar year 1977. It would have been preferable if at least 75% of the total hours in the year had been available but because of excessive

downtimes of the instruments this was not the case. It will be noted particularly, that during the months of August and September the instruments were inoperative. This was due to a major overhaul of the instruments and computer system during these months. However, from the remaining observations available it is possible to extract meaningful information as the following sections in the report will show.

Meteorological Data

Table 2 lists the percent of time in which each wind direction occurred for each month during 1977. It is clear that emissions from each wind direction contribute to the concentration of the pollutant being measured. It is further evident, however, that some wind directions are more predominant than others and consequently emission sources from these wind directions will bias the final results. For example, easterly wind directions occur the least amount of time, and therefore emissions from these directions (mostly D.C. and parts of Maryland, and motor vehicle exhaust emissions from Route 295) will have the least influence on the concentrations of pollutants being measured. On the other hand, it will also be noted that the westerly wind directions predominate at NRL. Consequently, emissions from these wind directions will bias the air quality data.

The prevailing wind direction during 1977 was NNW. The only local nearby emission sources from that direction is the Washington National Airport facility. It is not yet clear if emissions from this area are significant with respect to the NRL air quality data. Further inspection of the last column in Table 2 reveals that the second predominant wind direction was calm; occurring 12.9% of the time. This wind direction indicates that local emission sources from any wind direction will bias the air quality data and perhaps lead to abnormally high pollutant concentrations.

Table 3 lists the average prevailing wind direction during each hour for each month during 1977. The wind directions that occurred most of the time include NNW and calm. The wind directions that occurred the least amount of time are E, ESE, SE, and WSW. It should be kept in mind, however, that the atmosphere is a dynamic system and that wind from a given direction is not generally sustained for long periods of time. Consequently,

pollutant plumes tend to meander or swirl before reaching the air sampling probe. As a result, it is possible that emissions from one wind direction will be included with those emissions from the predominating wind direction occurring at that time; one may think of this as a sort of entrapment, or entrainment.

Table 4 lists the percent of occurrence that a given wind speed group occurred during each month of the year in which data were available. In decreasing order the occurrence of wind speed groups are, in general: 3.5 - 7.4 mph, 0 - 3.4 mph, 7.5 - 12.4 mph, 12.5 - 18.4 mph, and 18.5 mph and over. From this list it may be concluded that wind speeds are, on the average, rather low most of the time. Therefore, a poorly mixed atmosphere with respect to pollutants is more likely than a well-mixed atmosphere. This point is further brought out in Table 5 where the average wind speed is listed for each wind direction of each month during the year.

Pollutant Concentration Data

Table 6 lists the monthly average pollutant concentration that occurred during 1977. Also included are the yearly averages for each pollutant, and were calculated and based on the number of valid observations for each month. The yearly average may be questionable here due to the lack of data for the months of August and September. However, it is felt that the yearly averages are, at least, representative of the actual values.

Monthly and yearly times may be considered as long sampling periods in which wide fluctuations in concentrations are minimized or damped. Even so, some pollutants show wide differences in their monthly averages. O_3, for example, ranges from a low monthly average of 0.007 ppmv to a high monthly average of 0.040 ppmv. This is clearly a seasonal effect and indicates that O_3 formation is higher in the warmer months than the colder months. O_3, it will be recalled, is more likely to be formed when one of the prerequisites for oxidant formation is high ambient temperatures. Monthly SO_2 average concentrations are not so clearcut with respect to season because peak loads of this source varies with demand; increased fuel consumption during cold periods in the winter and increased power requirements for air conditioning during hot weather. NO_2 monthly average concentrations, on the other hand, vary

considerably over the year with a low of 0.018 ppmv during January and a high of 0.116 ppmv during June. The reasons for this seasonal effect are not yet clear. RHC monthly average concentrations also vary widely with a low of 0.04 ppmv during November and a high of 1.06 ppmv during June. In fact it will be noted that low RHC concentrations occurred during October, November, and December. It would appear as if RHC, the non-methane hydrocarbons, emissions were either effectively scavenged during this period of three months or were well-diluted in the ambient atmosphere. CO monthly average concentrations have a very pronounced seasonal character as shown by the data of this pollutant in the table. According to the concentration data, CO concentrations are higher in the cooler months and lower in the warmer months. This is a characteristic pattern for CO and shows up from year to year. It would be interesting to know why this trend with CO occurs especially since motor vehicle exhaust emissions are considered to be the major source of CO emissions, and road traffic density does not vary that much from month to month.

To get a more realistic picture of pollutant concentration fluctuations over shorter time-averaging periods the air quality data of Table 7 are of interest. In this table the maximum concentrations that occurred in each month for different time-averaging periods are listed. For any pollutant and within a given time-averaging period the data shows that wide concentration fluctuations can occur from month to month. This is shown by the highest and lowest values for each pollutant and for each time-averaging period. Some of these concentrations are rather high, especially for the 5-minute time-averaging period, and it is fortunate that these concentrations are not sustained for longer periods of time. Normally, though, except under the most abnormal conditions, pollutant concentrations decrease with sampling time. For example the 24-hour maximum concentration is lower than the 1-hour maximum concentration, and the 1-hour maximum concentration is lower than the 5-minute maximum concentration. This pattern is always the case with pollutant concentrations and, as a result, pollutant concentrations tend, in most cases, to be approximately log-normally distributed. In this type of distribution there are a few high concentrations and large number of low concentrations, i.e., most pollutant concentrations tend to be below the average concentration for a given time-averaging period. In some

extreme cases about 85% of the concentration values were found to be below the average concentration. In any case wide concentration fluctuations are due to variations in emission sources (number, type, location, strength, peak periods, etc.) and to meteorological conditions (air temperature, cloud cover, sunlight, relative humidity, pressure, turbulence, etc.).

If it is assumed that the same emission sources are available on a day-to-day basis with no significant change in output then it may be concluded that variations in meteorological conditions are more effective in causing pollutant concentration fluctuations than emission sources. Furthermore, the efficacy of scavenging mechanisms for pollutants depends on meteorological conditions.

A further analysis of the maximum concentration data is shown in Table 8 for O_3, SO_2, NO_2, RHC, and CO. This table lists, for each month, the hourly maximum concentration, the hour of the day in which it occurred, the day of the week, the wind speed, and the wind direction.

Some general conclusions that can be drawn from the data listed in Table 8(a) through 8(e), are that high hourly maximum concentrations can occur during any day of the week, and that westerly and calm wind directions are predominant. Sunday, it will be noted, appears quite frequently and suggests that emissions of the type emitted in the metro D.C. area do not fluctuate from day to day, even on weekends. The predominantly westerly influence indicates that emission sources from the Virginia sector (see Fig. 2) are predominant.

Specifically, Table 8(a) indicates that O_3 is highest in the afternoon hours and this is reasonable since O_3 formation is most likely at those times. Also, there is no correlation between high hourly O_3 concentrations and wind speed.

For SO_2, Table 8(b) reveals no significant relationships except that high concentrations occur from the westerly direction almost all of the time. This is well known at NRL because of the close proximity of a coal-fired electric power plant which lies west of the Laboratory.

For NO_2, it is clear from Table 8(c) that high concentrations occur at low wind speed, and that the

favorable time of day is around 9:00 a.m. (0900 hours) and at 7:00 p.m. (1900 hours).

High hourly RHC concentrations, Table 8(d), occurred mostly at calm conditions and at low winds; and some rather high concentrations from the easterly directions.

For CO, according to Table 8(e), high hourly concentrations occurred; (1) in two time periods, one in the morning and one in the late afternoon; (2) at low wind speeds; and (3) either at calm conditions or from an easterly direction. For this pollutant, and others, an easterly direction may be correlated with motor vehicle exahust emissions from Route 295 (see Fig. 2).

Table 8(a) through 8(e) lists the highest maximum concentrations that occurred during each month for a given pollutant during the year. However, it is of interest to find out if the highest concentration during the day occurred at any preferable time. Therefore, Table 9 was constructed to show this trend for each pollutant. This type of approach is worthwhile because it allows pollutant concentrations to be characterized with respect to patterns and trends on a day to day basis. From Table 9 the data establish that high O_3 concentrations are clustered within a narrow time frame, i.e., from 11:00 a.m. (1100 hours) to 5:00 p.m. (1700 hours) and peaking at around 2:00 p.m. (1400 hours). For SO_2 though, there is no apparent clustering of high hourly concentrations within a given time period. This in itself is revealing because it indicates high SO_2 concentrations can be spread out throughout the whole day. NO_2 is different from O_3 and SO_2 in that the maximum concentrations occur in two time periods during the day; one between 0600 - 1000 hours (6:00 a.m. - 10:00 a.m.) and the other between 1800 - 0100 hours (6:00 p.m. - 1:00 a.m.). High NO_2 concentrations, it will be noted, do not normally occur between 1100 - 1600 hours (11:00 a.m. - 4:00 p.m.). For high RHC concentrations it is difficult to come to any conclusions although a case can be made that motor vehicle exhaust emissions are not necessarily a predominant source of this pollutant in this area. Otherwise high RHC concentrations would have been better correlated with the morning and evening rush hour traffic period (6:00 a.m. - 9:00 a.m. and 3:30 p.m. - 6:30 p.m.). Inspection of the RHC data indicates that this is not the case. High CO concentrations, like NO_2, appear to have two peak periods

during the day: the peak periods are from 0700 - 0900 hours (7:00 a.m. - 9:00 a.m.) corresponding to the morning rush hour traffic period and from 1800 - 0100 hours (6:00 p.m. - 1:00 a.m.). The late evening peak period does not correlate well with the evening rush hour traffic period at all. Any explanation that might be offered at this time about the late evening peak period for high CO concentrations is not yet satisfactory.

Air Quality Standards

Air quality data generated at NRL can be usefully compared to the federal and D.C. ambient air quality standards issued for this purpose. By this means one can ascertain the air quality at the Laboratory by noting if the standards have been exceeded. For example, Table 10 lists the federal pollutant standards and the number of time these have been exceeded at NRL during 1977. Table 11 lists the D.C. pollutant standards and the number of times these were exceeded by the NRL data. From both Tables 10 and 11 it is found that the ambient air at NRL had some serious air pollution problems at certain times of the year. Although by no means excessive, as compared to other air quality data from local jurisdictions, the fact that the standards have been exceeded so many times is worrisome. At the same time this does not mean that the facilities at NRL generated those pollutants which were excessive. What the data do reveal is that more effecitve air pollution control systems are needed for those sources which emit copious quantities of pollutants into the atmosphere.

Table 12 lists the Air Quality Index (AQI) criteria for Metropolitan Washington and the number of times the NRL air quality data were exceeded. Comparing Table 12 with Tables 10 and 11 reveals that the AQI criteria are less severe than the federal and D.C. standards. Therefore, from the list in Table 12 it is seen that only O_3 exceeded the AQI cirteria and that only during the alert stage. Based on past analysis of the NRL data it does not seem likely that the SO_2, NO_2, and CO AQI values will be exceeded at NRL. It would have to be under abnormal conditions (meteorological), than heretofore encountered, before this can occur. For example, a prolonged drought, a prolonged stagnating high pressure system, a sustained temperature inversion period, and calm or low winds, are some of the prerequisites necessary to create abnormally high concentrations of one or more pollutants.

MISCELLANEOUS REMARKS

There are a few remarks worth mentioning at this time that do not fit into the general scheme of this report. The purpose of this section is to augment our existing knowledge about the NRL air quality data based on several years knowledge with the air monitoring program. For example:

(a) O_3 and SO_2 concentrations are high when the relative humidity of the atmosphere is low;

(b) high NO_2 concentrations are independent of the relative humidity of the atmosphere;

(c) high THC, CH_4, RHC, and CO may occur at high relative humidity of the atmosphere;

(d) with respect to the NRL air monitoring site some pollutants are more well-mixed in the atmosphere (NO_2) than some other pollutants (SO_2, RHC);

(e) daily surface-based temperature inversions are a common occurrence;

(f) high O_3 concentrations do not occur with high SO_2 concentrations;

(g) pollutants are transported through the atmosphere as clouds or puffs;

(h) generally all of the pollutants measured at the NRL site are not present in high concentrations at the same time;

(i) for a given pollutant different emission sources may predominate at different times of the day;

(j) odor from the D.C. Sewage Treatment Plant does not necessarily imply high pollutant concentrations;

(k) SO_2 in the NRL atmosphere tarnishes exposed copper and nickel specimens in short periods of time;

(l) with the exception of the heating plant, there are no other major emission sources at the Laboratory; and

(m) rain or snowfall are not 100% effective scavenging mechanisms.

Most of the above items will be discussed more fully in future reports.

FUTURE PLANS

To improve the effectiveness of an air monitoring program it becomes necessary from time to time to expand the analytical capability of the station; limited of course by budget restraints and manpower requirements. Consequently, it is proposed to expand the present air monitoring program to include air temperature and relative humidity sensors, a NO/NO_x and a CO_2 detector, expand the data acquisition system to accommodate and include the added sensors and detectors, and include some type of particulate matter monitor. In addition, a commercial type smoke detector is presently being converted to use as a smog detector.

In addition, the concept of the relative measure of variability of pollutant concentrations in air will be developed more fully for use as a routine method of analysis of air quality data (6).

SUMMARY

This report is the third in a continuing series of annual summaries of the air quality data measured at the NRL air monitoring station. Data reported are for ozone (O_3), sulfur dioxide (SO_2), nitrogen dioxide (NO_2), non-methane hydrocarbons (RHC), carbon monoxide (CO), wind speed, and wind direction. Variations in emission sources, meteorological conditions, and scavenging mechanisms are considered as the causes of the wide concentration fluctuations during any given time-averaging period for any given pollutant. A detailed discussion is presented on wind speeds and wind directions and their effect on pollutant concentrations. Consideration is also given to the maximum concentrations occurring each month during 1977 for the 5-minute, 1-hour, and 24-hour time-averaging periods, and the corresponding relationship with time of day, day of week, wind speed, and wind direction. Finally, some characteristic trends of pollutant behavior peculiar to the NRL air monitoring site are pointed out and discussed.

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TABLE 1

VALID HOURLY OBSERVATIONS

Month	O_3	SO_2	NO_2	RHC	CO	wind speed & direction
Jan	623	623	521	341	341	623
Feb	654	609	653	535	535	654
March	725	698	704	519	519	725
Apr	678	675	677	573	573	678
May	571	571	571	571	571	578
Jun	412	434	412	374	374	435
Jul	283	284	543	664	664	671
Aug	-	-	-	-	-	-
Sep	-	-	-	-	-	-
Oct	624	650	652	631	650	652
Nov	633	691	688	636	636	692
Dec	672	619	596	671	671	672
Total	5875	5854	6017	5515	5534	6380
% Occurrence*	67.1	66.8	68.7	63.0	63.2	72.8

*based on 8760 hours

TABLE 2

PERCENT OCCURRENCE OF WIND DIRECTION FOR EACH MONTH DURING 1977

Wind Direction	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec.	% Occurrence During 1977
N	1.3	2.4	4.4	6.6	4.5	4.0	10.6	-	-	7.7	2.7	10.9	5.6
NNE	1.3	2.0	1.4	2.2	3.5	3.0	8.6	-	-	12.3	14.5	8.5	5.9
NE	3.2	1.5	0.3	3.1	2.8	0.9	3.4	-	-	10.1	10.7	4.9	4.2
ENE	1.9	0.5	0.3	2.2	0.5	0.4	1.3	-	-	3.4	7.9	2.7	2.2
E	2.1	0.2	0.1	1.0	0.5	0.7	1.0	-	-	1.5	4.8	1.6	1.3
ESE	0.5	0.5	0.1	1.5	0.3	0.2	1.3	-	-	2.6	1.7	1.6	1.0
SE	0.2	0.8	0.6	1.8	1.0	0.9	3.1	-	-	1.2	2.7	3.3	1.6
SSE	2.7	4.3	6.6	2.2	3.6	2.9	8.5	-	-	7.1	4.0	3.4	4.2
S	5.6	10.9	10.3	7.4	8.5	6.5	11.5	-	-	8.0	6.1	7.3	8.3
SSW	4.7	11.3	7.9	6.0	5.9	6.5	10.5	-	-	6.6	5.5	8.9	7.5
SW	3.7	12.8	9.7	12.8	6.9	13.7	10.1	-	-	5.1	7.5	11.9	9.8
WSW	7.9	4.0	2.3	3.5	2.4	4.8	4.5	-	-	2.3	3.8	2.3	3.7
W	18.0	8.1	1.8	2.1	2.4	2.6	2.5	-	-	3.1	2.0	2.5	4.5
WNW	31.8	13.8	3.7	4.4	4.2	5.4	1.3	-	-	4.3	3.2	2.2	7.3
NW	2.7	5.0	15.6	8.6	10.7	8.8	4.9	-	-	7.7	10.3	11.2	8.5
NNW	1.0	10.9	17.1	9.6	5.2	22.4	16.8	-	-	17.2	12.6	16.7	12.9
calm	11.6	11.2	17.8	24.9	37.0	17.0	0	-	-	0	0	0.1	11.5

TABLE 3

PREVAILING WIND DIRECTION FOR GIVEN HOUR OF DAY

Hour Beginning At	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
00 (midnight)	WNW	SW	S	C	C	C	NNW	-	-	SSE	NNW	NNE
01	WNW	C	C	C	C	NNW	NNW	-	-	S	NNE	NNW
02	WNW	C	C	C	C	C	SW	-	-	NNW	NE	S
03	W	C	C	C	C	C	NNE	-	-	NNW	NNW	NNW
04	W	S	C	C	C	NNW	NNE	-	-	NE	NE	NW
05	WNW	S	C	C	C	C	NNE	-	-	NE	NE	NNW
06	WNW	C	C	C	C	C	NNE	-	-	NNE	NNE	SSW
07	C	C	C	C	C	NNW	NNW	-	-	NNE	NNE	S
08	C	C	NNW	SW	C	NNW	NNE	-	-	NNE	NE	NNW
09	WNW	WNW	NNW	C	C	NNW	SW	-	-	NE	NW	NNW
10	WNW	NNW	C	NNW	C	NNW	NNW	-	-	NE	ENE	NNW
11	WNW	WNW	NNW	C	C	NNW	NNW	-	-	NNW	NW	NNW
12 (noon)	WNW	WNW	NW	C	C	NNW	NNW	-	-	NNW	ENE	SSW
13	WNW	W	C	NNW	C	W	NNW	-	-	NNW	NNE	SW
14	W	SSW	NW	C	C	NW	NNW	-	-	NNW	SW	NNW
15	WNW	WNW	NNW	NNW	C	SW	NNW	-	-	NNW	NNW	SW
16	WNW	SW	SW	C	C	NNW	NNW	-	-	NNW	NNW	SW
17	WNW	WNW	NNW	NW	C	SW	NNW	-	-	NNW	NNW	NNW
18	WNW	WNW	NNW	C	C	SW	S	-	-	NNW	ENE	NNW
19	WNW	SSE	C	C	C	NNW	S	-	-	NNW	NNW	NNW
20	WNW	C	NW	C	C	N	SSW	-	-	NNW	NNW	NNW
21	WNW	NNW	NW	C	C	NNW	SSE	-	-	NNW	NNE	NNW
22	WNW	NNW	S	C	C	C	SSE	-	-	NNW	NNE	NW
23	WNW	C	C	C	C	C	SSE	-	-	NNW	NNW	NNW

TABLE 4

PERCENT OF OCCURRENCE OF WIND SPEED GROUPS

Wind Speed Group (mph)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0 - 3.4	22.6	22.0	30.5	47.2	55.5	31.8	2.8	-	-	2.9	5.6	3.4
3.5 - 7.4	31.5	33.3	36.7	33.8	23.0	39.2	68.1	-	-	55.8	61.8	50.7
7.5 - 12.4	31.3	26.1	18.3	17.1	12.5	21.5	25.6	-	-	29.4	22.8	31.4
12.5 - 18.4	9.6	13.9	10.5	1.9	5.9	7.0	3.4	-	-	10.1	8.5	11.6
18.5 - over	5.0	4.6	4.0	0	3.1	0.7	0	-	-	1.7	1.2	2.8

TABLE 5

AVERAGE WIND SPEED PER GIVEN WIND DIRECTION DURING 1977

Wind Direction	Average Wind Speed (mph)											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
N	6.7	7.6	5.1	6.4	9.3	6.5	6.4	-	-	8.7	5.4	8.0
NNE	5.8	6.4	3.3	4.5	5.6	5.5	6.1	-	-	6.9	5.3	7.0
NE	5.6	8.6	4.0	3.2	3.9	2.3	6.8	-	-	7.0	6.2	7.0
ENE	4.3	3.3	3.3	3.8	5.4	6.6	7.3	-	-	6.1	6.1	6.3
E	5.7	2.8	4.7	4.9	26.6	4.3	5.1	-	-	7.0	6.9	7.2
ESE	4.3	7.9	2.9	3.3	17.9	1.6	6.4	-	-	5.9	6.9	6.3
SE	8.1	5.3	4.3	4.0	13.9	3.2	7.8	-	-	6.1	5.5	6.6
SSE	3.1	5.5	5.7	3.5	4.4	3.7	5.9	-	-	5.6	4.9	4.7
S	4.3	4.7	5.4	3.5	5.0	4.3	6.6	-	-	5.7	6.0	5.7
SSW	5.1	4.8	4.9	4.1	5.6	4.6	6.1	-	-	6.0	6.2	6.4
SW	8.1	7.5	5.9	7.0	5.6	6.6	8.2	-	-	7.0	7.0	7.9
SWS	8.3	6.8	6.1	6.0	6.3	4.7	6.6	-	-	6.1	5.6	4.9
W	9.0	11.7	6.3	5.6	7.3	5.0	6.4	-	-	5.5	6.3	5.4
WNW	11.6	13.2	7.9	7.4	7.0	7.1	7.3	-	-	8.2	7.4	7.4
NW	5.9	10.4	11.6	6.4	10.0	6.5	6.3	-	-	10.5	10.6	12.3
NNW	6.0	12.0	10.8	6.7	12.0	10.0	7.1	-	-	10.8	10.4	11.3

TABLE 6

MONTHLY AVERAGE CONCENTRATIONS IN ppmv OF POLLUTANTS DURING 1977

Month	O_3	SO_2	NO_2	RHC	CO
Jan	0.007	0.052	0.018	0.28	1.92
Feb	0.010	0.029	0.055	0.48	1.22
Mar	0.012	0.023	0.079	0.24	3.77
Apr	0.013	0.023	0.051	0.40	0.63
May	0.015	0.020	0.047	0.22	0.32
Jun	0.020	0.020	0.116	1.06	0.98
Jul	0.040	0.023	0.078	0.07	0.95
Aug	--	--	--	--	--
Sep	--	--	--	--	--
Oct	0.018	0.015	0.075	0.08	1.14
Nov	0.013	0.015	0.028	0.04	1.17
Dec	0.012	0.022	0.061	0.06	1.62
Yearly Average	0.014	0.024	0.058	0.25	1.33

TABLE 7

MAXIMUM CONCENTRATIONS OF POLLUTANTS IN ppmv AT DIFFERENT TIME-AVERAGES FOR EACH MONTH OF 1977

Month	O_3			SO_2			NO_2			RHC			CO		
	5-min	1-hr	24-hr	5-min	1-hr	24-hr	5-min	1-hr	24-hr	5-min	1-hr	24-hr	5-min	1-hr	24-hr
Jan	0.196	0.037	0.019	0.607	0.310	0.079	0.101	0.071	0.040	5.89	1.13	0.44	8.05	7.12	3.04
Feb	0.057	0.031	0.020	0.414	0.208	0.049	0.198	0.187	0.101	10.18	2.15	1.06	8.24	7.03	3.80
Mar	0.030	0.026	0.016	0.472	0.216	0.042	0.211	0.184	0.112	7.60	3.21	0.53	27.74	9.79	8.41
Apr	0.044	0.043	0.023	0.834	0.199	0.043	0.158	0.146	0.092	14.89	2.20	0.74	4.63	3.45	1.33
May	0.081	0.078	0.031	0.457	0.187	0.054	0.134	0.118	0.075	3.10	1.16	1.06	4.50	2.25	0.48
Jun	0.092	0.089	0.033	0.509	0.190	0.044	0.269	0.249	0.211	17.10	4.88	4.31	5.20	4.34	2.00
Jul	0.259	0.147	0.086	0.295	0.106	0.036	0.487	0.245	0.157	14.52	1.75	0.19	5.24	3.85	2.06
Aug	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Sep	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Oct	0.073	0.067	0.035	0.186	0.070	0.034	0.131	0.118	0.101	17.75	2.36	0.23	7.96	5.76	1.86
Nov	0.055	0.052	--	0.212	0.076	0.031	0.076	0.073	0.055	2.44	0.82	0.10	7.07	4.93	1.27
Dec	0.137	0.055	0.028	0.192	0.081	0.034	0.172	0.173	0.091	5.08	1.82	0.40	14.47	12.41	3.69
highest value	0.259	0.147	0.086	0.834	0.310	0.079	0.487	0.249	0.211	14.89	4.88	4.31	27.74	12.41	8.41
lowest value	0.030	0.026	0.016	0.186	0.070	0.031	0.076	0.071	0.040	2.44	0.82	0.10	4.50	2.25	0.48

TABLE 8

MAXIMUM HOURLY CONCENTRATIONS IN ppmv AND CORRESPONDING CONDITIONS (HOUR OF DAY, DAY OF WEEK, WIND SPEED, WIND DIRECTION) FOR EACH POLLUTANT DURING EACH MONTH OF 1977

Month	Conc. (ppmv)	Hour of Day	Day of Week	Wind Speed (mph)	Wind Direction
Jan	0.037	1100	Thur	8	W
Feb	0.031	1400	Wed	11	SW
Mar	0.026	1600	Tue	0	C
Apr	0.043	1400	Tue	8	NW
May	0.078	1600	Tue	0	C
Jun	0.089	0000	Sat	0	C
Jul	0.147	1100	Tue	6	SSE
Aug	--	--	-	-	-
Sep	--	--	-	-	-
Oct	0.067	1500	Sat	9	WSW
Nov	0.052	1300	Wed	11	SW
Dec	0.035	1300	Sat	14	SW

(a) O_3

Month	Conc. (ppmv)	Hour of Day	Day of Week	Wind Speed (mph)	Wind Direction
Jan	0.310	1500	Sun	14	W
Feb	0.208	1300	Fri	15	W
Mar	0.216	1600	Wed	7	W
Apr	0.199	1000	Thur	7	W
May	0.187	2200	Thur	4	W
Jun	0.190	1200	Sun	6	W
Jul	0.106	0900	Wed	4	NNE
Aug	--	--	-	-	-
Sep	--	--	-	-	-
Oct	0.070	2200	Mon	4	W
Nov	0.076	1000	Tue	5	S
Dec	0.081	0700	Wed	8	W

(b) SO_2

TABLE 8 (Continued)

Month	Conc. (ppmv)	Hour of Day	Day of Week	Wind Speed (mph)	Wind Direction
Jan	0.071	0900	Sun	0	C
Feb	0.187	0900	Fri	0	C
Mar	0.184	0800	Fri	0	C
Apr	0.146	0900	Tue	0	C
May	0.118	2100	Thur	2	W
Jun	0.249	1900	Mon	8	NNE
Jul	0.245	1900	Thur	8	NNW
Aug	--	--	-	-	-
Sep	--	--	-	-	-
Oct	0.118	0900	Wed	4	WNW
Nov	0.073	1900	Tue	5	NNE
Dec	0.170	1500	Fri	8	W

(c) NO_2

Month	Conc. (ppmv)	Hour of Day	Day of Week	Wind Speed (mph)	Wind Direction
Jan	1.13	0200	Sun	0	C
Feb	2.15	0500	Sat	0	C
Mar	3.21	0100	Sun	0	C
Apr	2.20	0400	Tue	0	C
May	1.16	2200	Wed	0	C
Jun	4.88	0300	Mon	0	C
Jul	1.75	0900	Mon	5	ESE
Aug	--	--	-	-	-
Sep	--	--	-	-	-
Oct	2.36	1500	Wed	9	NNW
Nov	0.82	1400	Tue	3	NNE
Dec	1.82	1000	Wed	10	NNE

(d) RHC

TABLE 8 (Continued)

Month	Conc. (ppmv)	Hour of Day	Day of Week	Wind Speed (mph)	Wind Direction
Jan	7.12	0300	Sun	0	C
Feb	7.03	0900	Fri	0	C
Mar	9.79	2300	Sun	5	NNW
Apr	3.45	0700	Mon	0	C
May	2.25	0900	Wed	0	C
Jun	4.34	0300	Mon	0	C
Jul	3.85	2300	Mon	8	SW
Aug	--	--	-	-	-
Sep	--	--	-	-	-
Oct	5.76	0800	Tue	8	SE
Nov	4.93	2000	Wed	5	NNE
Dec	12.41	1000	Wed	10	NNE

(e) CO

TABLE 9

NUMBER OF TIMES THE HOURLY MAXIMUM CONCENTRATION OCCURRED IN A GIVEN HOUR*

Hour Beginning At	O_3	SO_2	NO_2	RHC	CO
0000 (midnight)	10	15	31	17	22
0100	10	8	5	9	3
0200	3	13	9	10	5
0300	4	8	6	7	2
0400	6	14	3	7	2
0500	2	11	5	5	1
0600	1	7	8	8	0
0700	0	9	16	11	32
0800	0	13	10	14	30
0900	1	18	14	12	8
1000	4	13	10	7	5
1100	17	10	2	7	2
1200 (noon)	32	12	4	4	1
1300	45	15	2	4	2
1400	71	17	1	2	1
1500	43	17	2	6	0
1600	36	12	3	7	6
1700	16	5	6	6	6
1800	5	3	13	10	11
1900	1	6	24	18	17
2000	3	3	16	14	4
2100	3	9	24	8	13
2200	2	12	16	16	8
2300 (11 p.m.)	3	21	27	25	28

*based on local time

TABLE 10

NATIONAL AMBIENT AIR QUALITY STANDARDS IN ppmv AND NUMBER OF TIMES EXCEEDED AT NRL DURING 1977

POLLUTANT	STANDARDS		NUMBER OF TIMES EXCEEDED
SO_2	primary	0.03 (aam)* 0.14 (24-hr)	none
	secondary	0.50 (3-hr)	none
CO	primary and secondary	9 (8-hr) 35 (1-hr)	20 none
O_3	primary and secondary	0.08 (1-hr)	34
RHC	primary and secondary	0.24 (3-hr)**	86
NO_2		0.05 (9 a.m.)*	exceeded

* annual arithmetic mean

** 6 a.m. - 9 a.m.

TABLE 11

DISTRICT OF COLUMBIA AIR QUALITY STANDARDS IN ppmv AND NUMBER OF TIMES EXCEEDED AT NRL DURING 1977

POLLUTANT	STANDARDS	NUMBER OF TIMES EXCEEDED
SO_2	primary	
	0.029 (aam)*	none
	0.109 (24-hr)	none
	0.323 (1-hr)	none
	secondary	
	0.020 (aam)	exceeded
	0.086 (24-hr)	none
	0.273 (1-hr)	1
O_3	primary and secondary	
	0.08 (1-hr)	34
RHC	primary and secondary	
	0.24 (3-hr)**	86
NO_2	primary and secondary	
	0.05 (aam)**	exceeded

* annual arithmetic mean

** 6 a.m. - 9 a.m.

TABLE 12

METROPOLITAN WASHINGTON COUNCIL OF GOVERNMENTS AIR QUALITY INDEX CRITERIA (ONE-HOUR AVERAGES)*

	Alert Stage [ppm (v/v)]	Warning Stage [ppm (v/v)]	Emergency Stage [ppm (v/v)]
O_3	0.10**	0.40	0.50
SO_2	0.70	1.40	1.85
NO_2	0.60	1.2	1.6
CO	60	90	110

* Table includes only those pollutants monitored at the NRL air monitoring station.

** Exceeded 23 times.

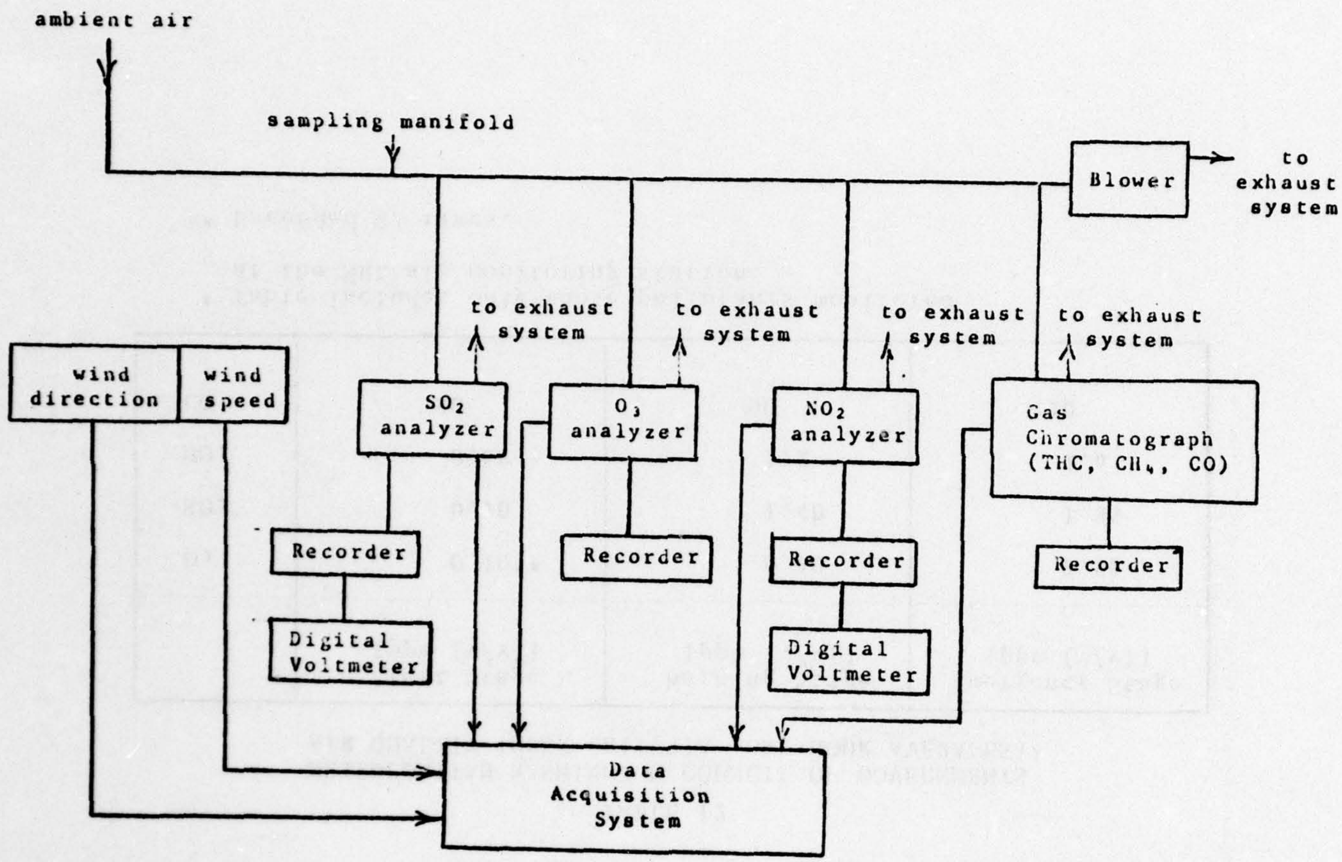

Fig. 1 — NRL air monitoring station

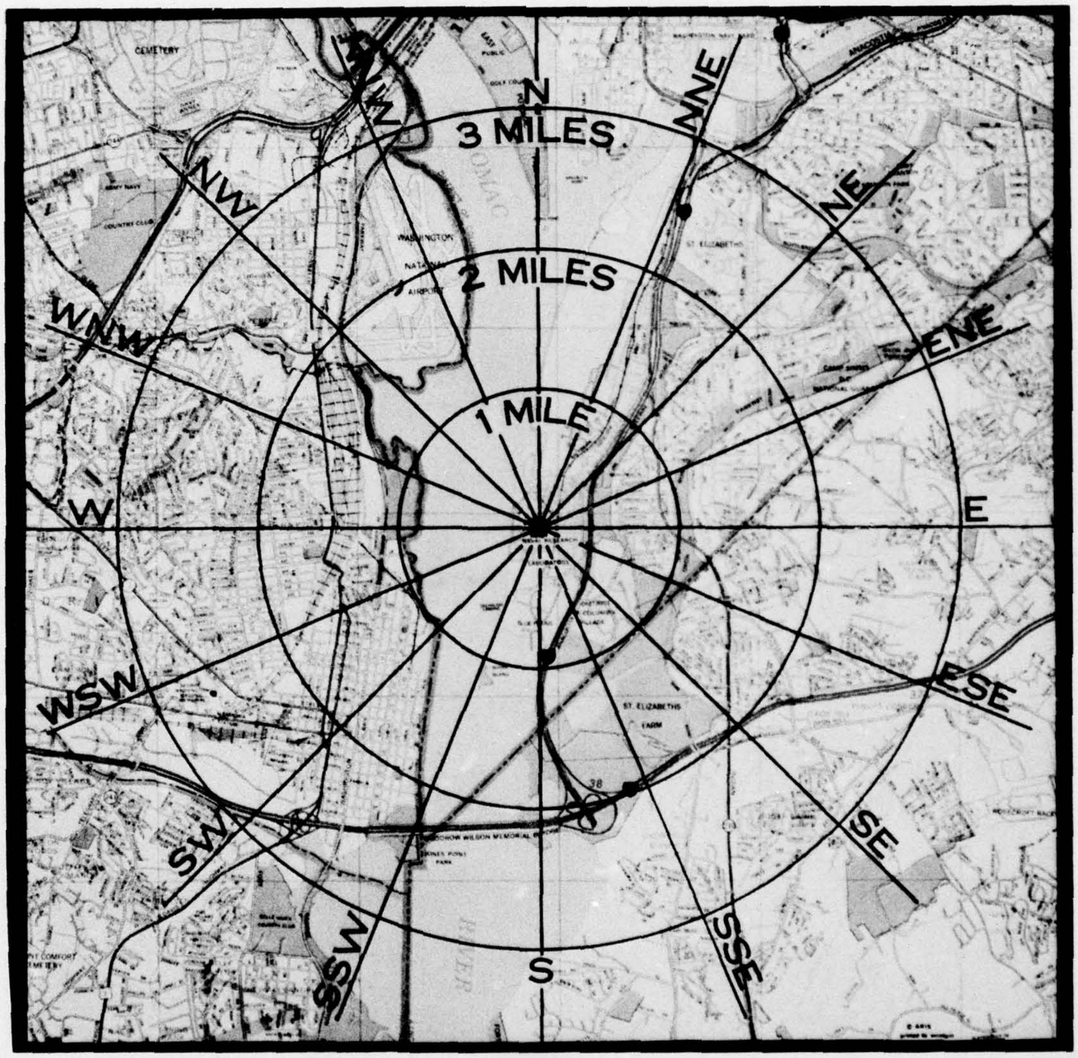

Fig. 2 — Radial and directional map of NRL and vicinity